# Energetic Electron Populations in the Magnetosphere During Geomagnetic Storms and Substorms

Summary Final Research Report

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by

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This report summarizes the scientific work performed by The Aerospace Corporation under NASA Grant NAG5-10278, "Energetic Electron Populations in the Magnetosphere during Geomagnetic Storms and Substorms." The period of performance for the Grant was March 1, 2001 to February 28, 2002. The following is a summary of the Statement of Work for this Grant. Use data from the PIXIE instrument on the *Polar* spacecraft from September 1998 onward to derive the statistical relationship between particle precipitation patterns and various geomagnetic activity indices. We are particularly interested in the occurrence of substorms during storm main phase and the efficacy of storms and substorms in injecting ring-current particles. We will compare stormtime simulations of the diffuse aurora using the models of Chen and Schulz [2001a,b] with stormtime PIXIE measurements.

Anderson and Chen [2002] studied global auroral X-ray data from two isolated substorms and two substorms that occurred during magnetic storms. The X-ray emission patterns associated with isolated substorms differed from those associated with substorms taking place during storms. For the isolated substorms, emissions were initially seen at onset in the premidnight-to-midnight sector and then spread toward dawn. The emissions extended beyond 12:00 MLT, with the most intense emissions occurring in the postdawn sector. The time scales for the appearance of X-ray emissions in the morningside MLT sectors were consistent with the drift times of electrons, of sufficiently high energy to produce X rays detectable by PIXIE, under the influence of a magnetospheric electric field inferred from ionospheric ion-drift measurements. During the recovery phase of the isolated substorms, the emissions died away gradually at increasing MLT, with the last of the emissions, in the noon sector, disappearing ~3-4 hours after substorm onset. During the stormtime substorms, emissions were seen in the premidnight-to-midnight regions at onset and spread toward dawn as in the isolated substorms. However, the emissions did not reach much beyond about 9 - 10 MLT, and very intense emissions were seen in the predawn MLT sectors. These intense predawn emissions were observed throughout the stormtime periods and were associated with significantly enhanced magnetospheric convection. There were brief reductions in intensity in the morningside emissions shortly after substorm onset, consistent with a brief reduction in the cross-tail electric field, followed by intensification again in the predawn sector on a time scale consonant with drifting electrons under the influence of a magnetospheric electric field. The authors concluded that the differences between the temporal evolution and morphology of the auroral X-ray emissions during isolated and stormtime substorms were the result of pitch-angle scattering mechanisms whose MLT distribution and intensity are dependent on the strength of the magnetospheric electric field.

McKenzie, *et al.*, [2002] have completed a multispectral analysis of auroral emissions during and after a substorm that occurred in the recovery phase of a magnetic storm on January 14, 1999. The analysis combined PIXIE X-ray spectral images, UVI LBHL and LBHS images, data from ground-based photometers stationed at Poker Flat and Fort Yukon, AK, and riograms from the HAARP riometer at Gakona, AK. The ground-based data were in the 03:00-04:30 MLT sector. The X-ray, UV, and ground-based photometer data were used to derive total incident auroral electron fluxes and average electron energies, and the riometer data provided insight into relatively low fluxes of high-energy electrons that were not otherwise discernible.

The parameters characterizing the incident auroral electrons were derived from the X-ray data alone, from the UVI data alone, and by a technique that used both *Polar* data sets. In most local time sectors, the average electron energies derived from the X-ray spectra were higher than those derived from the UVI LBHL/LBHS flux ratios. The incident electron energy flux and mean electron energy were derived by making a single fit to the observed X-ray spectrum, using an assumed generic spectral form (Maxwellian). With this technique the two derived parameters are not independently determined and are not independent of the assumed spectral form. This limitation is common to spectral analysis that relies solely on X-ray spectra over a limited energy range. In contrast, the LBHL flux provides a direct measure of the incident electron flux that is only weakly dependent upon the spectral shape. Once the incident electron flux is fixed, the total PIXIE detector counting rate is a sensitive function of the average electron energy, regardless of the spectral shape, provided that the average electron energy is less than about 15 keV. We then have a "two-photometer" technique that yields the parameters describing the incident electron population independent of the spectral shape. One "photometer" operates in the UVI LBHL band and the other measures the 2-11 keV X-ray flux. The average electron energies derived by the "two-photometer" technique agreed well with the PIXIE results, except near midnight MLT, where they were more in line with the lower energies derived from the LBHS/LBHL ratio.

Ground-based photometers deployed at Poker Flat and Fort Yukon, AK, derived total electron flux and average electron energy from spectral line measurements at 427.8, 630.0, 844.6, and 871.0 nm. The derived parameters agreed well with the UVI results, but the average energies derived from the X-ray spectra were slightly, but significantly, higher. Average energies from the UV/X-ray technique agreed well with those derived from the X-ray spectra alone. The HAARP imaging riometer at Gakona, AK, observed absorption above 2 dB during the period for which photometer data were available, with brief localized excursions as high as 4 dB. Such observations are indicative of a high-energy electron component that was not detected in the X-ray spectral analysis. When the PIXIE data were corrected for the presence of a high-energy electron component, the agreement among the three data sets improved significantly. This study illustrates the value of combining a large variety of observational data sets in order to characterize auroral electron populations. This paper was submitted to the *Journal of Geoephsical Research - Space Physics* and is currently being revised in response to the referees' reports.

References

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